Maximize Operator Effectiveness:

*High Performance HMI Case Studies, Recommendations, and Standards*

Part 2 of 2

A PAS White Paper
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# Table of Contents

Introduction and Overview ............................................................................................................................. 1  
A Real World Case Study and Test of HPHMI Concepts .................................................................................. 3  
The Level 1 Overview ...................................................................................................................................... 4  
The Level “1.5” Pulverizer Overview Graphic ............................................................................................... 5  
The Level 2 Pulverizer Control Graphics ....................................................................................................... 6  
Abnormal Situation Response Graphics ......................................................................................................... 7  
The Testing .................................................................................................................................................... 8  
The Results .................................................................................................................................................... 9  
PowerGraphiX® .............................................................................................................................................. 9  
Paradigm Busting: The Pipeline Overview ..................................................................................................... 13  
A Review of HMI Standards .......................................................................................................................... 16  
   API-1165: Recommended Practice for Pipeline SCADA Displays ............................................................. 17  
   ISA-101: Human-Machine Interfaces for Process Automation Systems .................................................... 17  
The PAS Seven Steps HPHMI Work Process ............................................................................................... 21  
HPHMI Implementation on a Budget ........................................................................................................... 22  
Conclusion .................................................................................................................................................... 23  
Typical Table of Contents of an HPHMI Philosophy and Style Guide ....................................................... 24  
About the Authors ......................................................................................................................................... 27  
References ...................................................................................................................................................... 28
Introduction and Overview

The process control and automation industry has spent billions on improving process safety via complex, instrumented systems. Yet, we continue to frequently see industrial incidents, accidents, and fatalities in the news. The causes are generally not the failure of such automated systems but are instead the result of a wide variety of human errors. PAS firmly believes that addressing the causes of human error and the improvement of Operator Effectiveness is of the highest importance. The proper use of such technologies as High Performance HMI™ (HPHMI) and Alarm Management can actually save lives and prevent injuries. Detailed information on these should not be withheld, and that is why we offer this and other white papers freely. They can also significantly lessen process upsets, improve process efficiency, and increase productivity.

The human-machine interface (HMI) is the collection of screens, graphic displays, and other technologies used by the operator to monitor and interact with the control system (typically DCS or SCADA). Several major accidents, such as the Texas City refinery explosion in 2005, have cited poor HMIs as a significant contributing factor. The design of the HMI plays a critical role in determining the operator’s ability to effectively manage the operation, particularly in quickly detecting and resolving an abnormal situation, which is the most important task of an operator. A poor HMI can actively interfere with this ability.

For several reasons, the current designs and capabilities of most HMIs are far from optimal for running the kinds of complex operations we have in industry. Most HMIs consist simply of schematic or P&ID style graphics covered in numbers. Such displays provide the operator large amounts of raw data but almost no real information. They are difficult to interpret and provide inadequate situation awareness to the operator.

Since we published The High Performance HMI Handbook in 2008, improving HMI has become one of the hottest topics in the automation industry. In that book, we explained exactly why most current HMI practices were poor, and we put forth the proper principles and details for making graphics significantly better. Many companies have adopted those principles and have completed migrations to improved graphics. Many more have such efforts currently underway.

This two-part paper provides a history, justification, and detailed plan of action for the improvement of a process control HMI. Here is an overview of the contents.
Part 1 (Separate Document)

**Examples:** We provide typical examples of common but poor HMIs, along with highly detailed depictions of improved methods that provide for much better operator situation awareness and control.

**Principles:** We cover the most important aspect of High Performance HMI, the display of information to the operator rather than raw data. Many other necessary graphic principles including the correct way to use color are provided. Depictions of detailed graphic elements are included.

**Hierarchy:** HPHMI graphic designs must reflect a proper hierarchy - the exposure of additional detail as needed. We include examples of graphics that illustrate this hierarchy, along with the work processes used to design such graphics.

Part 2

**Case Studies:** Since the publication of our 2008 book, many projects have provided for the development of real world case studies. We include two such studies in this paper. The first was conducted by the Electric Power Research Institute (EPRI) but is applicable to all types of process operations. The second shows how a major company has improved performance and significantly lowered costs via company-wide adoption of standardized High Performance graphics. This has led to a major HPHMI product innovation for the power industry: PowerGraphiX®.

We also provide an example as to how “out-of-the-box thinking” can address HMI issues, in the discussion of a Pipeline System Overview Display.

**Standards Review:** Two standards documents available on HMI are discussed, including the ANSI/ISA-101.01-2015: Human Machine Interfaces for Process Automation Systems released in August 2015.

**HPHMI Work Processes and Implementation Guidance:** The work process for HMI improvement is described. We also address the most common issues encountered in HMI improvement and cost effective ways to transition to High Performance graphics.

If your facility utilizes a process control system with a computer-based HMI, you will find this information useful. This white paper augments the detailed content in *The High Performance HMI Handbook.*
A Real World Case Study and Test of HPHMI Concepts

The following section is taken from a study conducted by the Electric Power Research Institute (EPRI).


The EPRI study tested the HPHMI concepts in this paper at a large, coal-fired power plant. The plant had a full and accurate simulator used for operator training. The existing graphics on the simulator (created in the early 1990s) operated the same as those on the actual control system. PAS was retained to prepare several High Performance graphics for the simulator. Several operators were then put through multiple abnormal situations using both the existing and the new High Performance graphics.

Four examples of the existing graphics are in Figure 1. They have the following characteristics:

- Many controller elements are not shown on any of the existing graphics.
- No graphic hierarchy.
- No Overview.

![Figure 1: 1990s Graphics from the EPRI HPHMI Test](image-url)
- Numbers and digital states are presented inconsistently.
- Poor graphic space utilization.
- Inconsistent selectability of numbers and elements.
- Poor color choices, overuse, and inconsistencies.
- Bright red and yellow used for normal conditions.
- Poor interlock depiction.
- No implemented trends ("trend-on-demand" rarely used by the operators).
- Alarm conditions generally not indicated on graphics – even if the value is a precursor to an automated action.

The operators used dozens of such graphics to control the process. PAS prepared the following High Performance graphics:

- Power Plant Overview (Level 1) – Figure 2
- Pulverizer Overview Graphic (Level “1.5”) – Figure 3
- 8 Individual Pulverizer Level 2 Control Graphic – Figure 4
- Runback 1 and 2: Special Abnormal Situation Graphics – Figure 5

The Level 1 Overview

**Figure 2:** Example Level 1 Display

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The Overview graphic shown in Figure 2 (repeated from the Part 1 document) shows the key performance indicators of the entire system under the operator’s control. The most important parameters incorporate trends. It is easy to scan these at a glance and detect any non-normal conditions. Status of major equipment is shown. Alarms are easily detected.

The operators found the overview display to be far more useful than the existing graphics in providing overall situation awareness and also very useful in detecting burgeoning abnormal situations.

The Level “1.5” Pulverizer Overview Graphic

The operator controls eight identical, heavily instrumented, and complex pieces of equipment called coal pulverizers. At normal rates, seven are in use and one is on standby in case of a problem. The seven that are running should be showing almost identical performance. It was immediately apparent that an “Overview” graphic of just these eight items would be useful to the operators, since much of their activity is in monitoring and manipulating them. Being mechanical, they are subject to a variety of problems and abnormal conditions. There were three separate existing graphics needed for monitoring and controlling each pulverizer, 24 in total for them all. Monitoring using 24 graphics was difficult for the operators.

**Figure 3:** The Level “1.5” Pulverizer Overview
The new Pulverizer Overview in Figure 3 depicts more than 160 measurements on a single graphic! The key to making this understandable is that the devices are supposed to run alike. Instead of blocks of indicators for each pulverizer being grouped together, the same measurement from each pulverizer is grouped together. Any individual unit operating differently than the others stands out. The unit that is in standby service also is easily seen. Air damper command vs. actual positions, a consistent source of problems, is clearly shown.

Note that the trends seemingly violate our recommendation of showing no more than three or four traces on a single trend. In this case, what the operator is looking for is any trend line that is not “bunched in” with the others. For such a condition, having these eight traces was acceptable. Note that the standby pulverizer’s trace is normally on the bottom.

Even with such a “dense” information depiction and with so many measurements, the operators found it easy to monitor all eight devices and easily detect burgeoning abnormal situations. It is easy to scan your eye across the screen and spot any elements that are inconsistent (Pulverizer “B” in the depiction). Alarm conditions are also easy to spot.

Note that control actions are not taken on this screen but rather on the eight individual Level 2 graphics, one for each pulverizer. This graphic is “in-between” Level 1 and 2, as it is an overview of a complex sub-part of the operator’s responsibility. The most common sources or problems are depicted.

The Level 2 Pulverizer Control Graphic

Figure 4: Level 2 Pulverizer Control
Rather than using the three separate graphics shown to control each pulverizer (24 graphics total), a single Level 2 graphic for each pulverizer was created with everything needed to accomplish all typical control manipulations.

While complex in appearance to the layman, the trained operator had no difficulty in understanding and accessing everything they needed for pulverizer startup, shutdown, and swap situations that arose during the test. Much of the text on the screen has to do with the status of existing semi-automated sequences that sometimes require operator intervention. Everything on the screen is selectable, and when selected the standard faceplate for the element appears in a reserved “faceplate zone” rather than floating around the screen obscuring the graphic. Element manipulation is made via the faceplate.

Abnormal Situation Response Graphics

The operator response for many abnormal plant situations is to cut rates by half, from 700MW to 350MW. Called a “Runback,” this is a complicated and stressful procedure that takes about 20 minutes to accomplish. If done incorrectly or if important parameters are missed, the plant can fall to zero output, a very undesirable situation. One of the main purposes of the simulator was to periodically re-train the operators for this situation. The operators have to use more than a dozen of the existing graphics to accomplish the task, involving a lot of navigation activity around screen callups and dismissals along with control manipulation.

However, in more than a decade of such training, it had never occurred to anyone to design special graphics specifically designed to assist in this task. This demonstrates the power of inertia in dealing with our HMIs. Specific Abnormal Situation Detection and Response graphics are an important element of an HPHMI.

PAS created two “Runback” graphics designed specifically to assist in this task. Every element that the operator needed to monitor and control the runback situation effectively was included on them. In use, the operators placed them on adjacent physical screens. Figure 5 shows “Runback 1;” Runback 2 was similar. The reserved faceplate zone is on the lower right.

As a simple example of providing information rather than data, consider the trend graph at the upper left of Runback 1. To be successful, the rate of power reduction must not be too slow or too fast. The existing graphics had no trend of this, simply showing the current power megawatt number. This new trend graph had the “sloped-line” element placed next to it, indicating the ideal rate of power reduction, the full load zone, and the target half-rate zone. On the figure, the actual rate of drop is initially exceeding the desired rate, and that condition is easily seen. (Note: It would have been more desirable to have the sloped lines on the background of the trend area itself, but the DCS could not accomplish such a depiction. This is a compromise, but one the operators still found to be useful.)
The Testing

Eight Operators, averaging eight years of console operating experience each, were used in the test. They received only one hour of training with the new graphics prior to the start of testing. (This was to address the common objection of “Changing our graphics would take months of retraining!”) They were tested on four increasingly complex situations, each lasting about 20 minutes.

- Coal Pulverizer Swap Under Load
- Pulverizer Trip and Load Reduction
- Manual Load Drop with Malfunctions
- Total Plant Load Runback

All operators did all scenarios twice, using the old graphics alone, and the HPHMI graphics. Half used the old graphics first (without having been shown the new graphics), and half used the new HPHMI graphics first.

Quantitative and qualitative measurements were made on the performance of each scenario (e.g., detection of the abnormal condition, time to respond, correct and successful response).
The Results

The High Performance graphics were significantly better in assisting the operator in:

- Maintaining situational awareness.
- Recognizing abnormal situations.
- Recognizing equipment malfunctions.
- Dealing with abnormal situations.
- Embedding knowledge into the control system.

Operators highly rated the Overview screen, agreeing that it provided highly useful “big picture” situation awareness. Even with only one hour of familiarization with the new graphics, operators had no difficulties in operating the unit. The High Performance graphics are designed to have intuitive depictions.

Very positive Operator comments were received on the analog depictions, alarm depictions, and embedded trends. There were consistent positive comments on how “obvious” the HPHMI made the various process situations. Values moving towards a unit trip were clearly shown and noticed by the operators.

The operators commented that HPHMI would enable faster and more effective training of new operations personnel. The negative operator comments generally had to do with lack of familiarity with the graphics prior to the test (which was intentional).

The best summary quote was this one:

“Once you got used to these new graphics, going back to the old ones would be hell.”

The effect of inertia being the controlling factor for HMI change was once more confirmed. The existing HMI had been in use since the early 1990s, with simulator training for more than a decade. Despite clear deficiencies, almost no change to the existing HMI had been made since inception.

Operators using the existing graphics first in the test were then asked “What improvements would you make to the existing graphics to help in these situations?” In response, there were very few or no suggestions!

However, operators using the existing graphics after they used the HPHMI graphics had many suggestions for improvement, namely analog depictions, embedded trends, alarm depiction, consistent navigation, etc.

So, people get “used to” what they have - and do not complain or know what they are missing if they are unfamiliar with these HPHMI concepts.

A lack of complaints does not indicate that you have a good HMI!
After the publication of *The High Performance HMI Handbook*, Southern Company, a major United States power generation and distribution company, took notice of it. Southern Company operates more than 280 nuclear, coal, oil, gas, biomass, wind, solar, and hydro generating units at more than 75 power plants, with a combined capacity of more than 45,000 megawatts. They are well known for their forward thinking and engineering approach to problem solving.

Southern had traditionally designed graphics much like others have. This was either using the perspective of an engineer looking at the P&IDs, or by delegating graphics creation to operators, who tended to arrange screens of numbers suiting their individual preferences. Neither of those approaches led to a consistent or satisfactory end product.

In 2009, Southern suspected that there “had to be a better way” to present information to their operators. Significant problems were being found as new projects were each being treated as custom HMI implementations. Existing control rooms had significant screen and graphic proliferation – with many plants having more than 500 different graphics used for control and creating significant HMI maintenance problems.

An in-house study was made and identified these common deficiencies:

- Few internal standards were in place.
- Personal graphic preferences resulted in each control project being a custom, inconsistent solution.
- Large HMI inconsistencies existed between identical plants.
- Significant retraining was required for personnel transfer.
- The over-abundant use of color incorporated in their graphics was not an aid to the operator.
- Individually plant-customized graphics led to significant impacts to cost, schedule, and consistency.

Southern concluded that the graphics portion of a controls project should be an “engineered solution,” just like the rest of the project. After considerable research, they recognized that the principles and design practices covered in *The High Performance HMI Handbook* dealt with all the issues they identified and went beyond them. Managerial support of a major improvement

*Figure 6: Original Control Room and How it Grew After DCS Conversion*
An effort was obtained. A test case project was chosen, involving a DCS conversion for two coal-fired generation units. HPHMI Workshops were held and workgroups formed. Corporate-wide operations experts designed template Level 1 and 2 graphics based on task analysis. The screen layout was driven by the Operator’s thought processes. The goal was total fleet standardization of High Performance graphics.

The test project was successful and then further proven in 17 plant conversions with more underway. Operator response is positive:

- “I can see problems coming before they happen.”
- “You got it right.”
- “I didn’t like it at first, but I do now.”
- “I wish I had this when I was learning to operate.”
- “I can find what I need now.”
- “I don’t have to jump around between screens to operate.”

The number of graphics used to control a plant was reduced from a typical value of 300-600 to approximately 80. Southern Company has documented both performance improvements and substantial costs savings in these areas:

- Improved operator situation awareness.
- Improved abnormal situation detection and handling.
- Reduced engineering time and cost for new plants, conversions, and modernizations.
- Reduced hardware costs (fewer workstations).
- Reduced licensing cost for control system software.
- Reduced ongoing maintenance cost.
- Reduced ongoing cybersecurity cost (fewer workstations and licenses).
- Reduced training costs.
- Upsets avoided (anecdotal evidence and cases).

Now designated as PowerGraphiX®, these graphics represent thousands of hours of design, improvement, and actual in-operation experience. The measurements and statuses shown on each graphic have received highly detailed review and proof testing by experienced power engineers.
industry experts. The designs, layouts, and functionalities are the right choices for implementation of a proper graphic hierarchy and HPHMI. They support maximum functionality for effective operator monitoring and control.

The power generation industry is much more consistent in plant design than is the petrochemical / chemical industry. This makes it possible for advancements such as PowerGraphiX to be incorporated much more easily and inexpensively by other companies. Southern and PAS realized that making PowerGraphiX available to the power industry would benefit overall operational effectiveness as well as safety.

To that end, PAS provides PowerGraphiX to the power industry. Here are a few of the many features and benefits included in PowerGraphiX.

Features:
- Documented HMI Philosophy & Style Guides.
- Layouts and templates for Hierarchy Levels 1, 2, 3, & 4.
- Object Libraries.

Benefits:
- Reduced engineering time and cost (Note that it costs at least as much to build or migrate a bad graphic as a good one.)
- Improved control system HMI consistency.
- Improved operator situation awareness and effectiveness.
- Effective use of large screen displays.
- Reduced ongoing HMI maintenance cost.
- Reduction in number of graphics.

These platforms are initially supported, and more are being developed. All product names are property of their respective owners and used in this paper for identification purposes only:
- ABB Symphony Plus ®
- Emerson Ovation ®
- Emerson Delta-V ®
- Invensys FOX IA ®
- Honeywell Experion ®
- Alstom Alspa 6 ®

Plant Types:
- Coal Fired.
- Combined Cycle.
- Supercritical.

For more information on PowerGraphiX, visit www.pas.com/PowerGraphiX or email at info@pas.com.
Paradigm Busting: The Pipeline Overview

This is an example of the kind of out-of-the-box thought process involved in re-examination of some of our HMI paradigms. The pipeline industry (including the water and wastewater segment) typically involves a process network of pipelines and processing facilities spread over large geographical area.

That industry has the typical P&ID-covered-in-numbers approach to graphics involving the facilities. They also have usually developed an “Overview” type of display. The paradigm for that is as shown in Figure 8, a map covered in numbers. By now, you should have guessed this!

Certainly some geographic detail is relevant to the role of the operator in this case. But is all of this detail relevant or helpful? Or is it a distraction? Is a map covered in numbers any better than a P&ID covered in numbers? The question is - what would be better?

It is a great tradition in engineering to build on the work of others – to adapt and enhance concepts that are successful in other domains. The trick is to have a wide enough view of the topic to recognize an applicable solution. It is to ask, “Has anyone else solved a similar problem?” In this case, the answer is yes, and in a big way.

A map of the very complex 1908 London Underground subway system is shown in Figure 9.
The user of this map is the subway rider. It is not that easy to interpret, for the purpose of figuring out the best route from your current position to the destination, using which subway lines, and changing at which stations. And there is time pressure – you are looking at the map, and the train has just pulled in next to you. Do you get on this one or the next one? Hurry!

It took about three decades for something better to be produced. In 1936, Engineer Harry Beck came up with a radically different depiction. He determined these questions to be the key ones for the subway rider:

- Where am I now (what station)?
- Where am I going (what station)?
- What lines service this station and where do they go?
- Where do I change trains?
- How many stops until my destination?

Even more importantly, he realized that there were many things that the subway rider did not need to know:

- Am I going around a curve?
- Am I passing under a river or near another train line?
- What is the relative distance between stations?
- Am I traveling in a specific direction (N,S,E,W) in between stations?

Beck realized that depicting topology, and not geography, was the key.

In the revised map, every line is horizontal, vertical, or at 45 degrees - even the River Thames. There is just enough geography and landmark depiction for the rider to orient their current position and find their destination station. It is fast and easy to pick out an efficient route, even for the novice rider.

Since 1936, the London Underground has continued to grow in complexity, but Beck’s Paradigm still works. It has become an iconic image, so functional that it has been universally adopted.

How can this paradigm be adapted to a Level 1 Overview display for a pipeline network? There are geographic cues important to a pipeline operator.

![Figure 10: Harry Beck’s 1936 London Underground Map](image)
For example, the location of a station or spill relative to state lines can mean that different regulations, reporting requirements, or emergency procedures apply.

Task analysis has shown these to be some important things for depiction:

- Important status conditions and alarms.
- Significant highway crossings.
- Significant waterway crossings.
- Neighborhoods if adjacent to pipeline.
- Important boundaries (i.e., state lines).
- Pressure profiles.
- Analog indicators showing station performance.
- Direction and content indicators.
- Important trends.
- Topology, not geography.

A conceptual Pipeline Overview Display with these elements is shown in Figure 11.

**Figure 11:** A Conceptual Pipeline Overview Display

HMI design is not simply arranging objects from a library onto a screen. There is room for a creative approach, as long as the proper principles are reflected in the design. When faced with an unusual process depiction problem, look at how similar situations have been solved in other areas, and then adapt them.
A Review of HMI Standards

Many readers of this white paper will already have *The High Performance HMI Handbook* and may be curious about other HMI-related documents. In this section, we review the API-1165 Recommended Practice and the ISA-101 HMI Standard released in August 2015.

We need to be precise in our language when discussing standards. In this section, the term “standard” applies only to a document that is produced in documented accordance with a strict methodology that involves balance of interests, consensus, and a stringent review and documentation process. Recognized bodies like the ISA follow these principles in issuing documents they call standards. Other organizations (e.g., EEMUA) do not, and the documents they produce are essentially books and reports, not standards.

When standards are issued by a recognized body, they acquire the status of being a “recognized and generally accepted good engineering practice (RAGAGEP).” This clumsy acronym denotes something very important, because regulatory agencies can and will cite the principle of RAGAGEP as being enforceable, as a “catch-all.”

Standards are highly restricted in their allowable content. Standards intentionally describe the minimum acceptable and not the optimum. By design, they focus on the “what to do” rather than the “how to do it.” Standards intentionally do not have detailed or specific “how-to” guidance – the kind of guidance that most people actually want or need, but that we do not want to be mandatory. Standards do not contain examples of specific proven methodologies or detailed work practices.

Other than *The High Performance HMI Handbook*, and this much expanded white paper, there are very few authoritative documents that address process control HMI. Here is a discussion of two of them.

API-1165: Recommended Practice for Pipeline SCADA Displays

API documents are often considered as RAGAGEP by their regulatory agency, PHMSA (Pipeline and Hazardous Materials Safety Administration). In 2006, API issued a document on SCADA HMI displays. There are some significant inconsistencies within that document. Overall, the concepts incorporated in the text portion of the document are valid. It mentions several good practices. The examples provided, however, contain several depictions that are in direct violation of the principles in the text.
For example, Section 8.2.4 states, “Color should not be the only indication for information. That is, pertinent information should also be available from some other cue in addition to color such as a symbol or piece of text.”

Yet throughout the remainder of the document, examples are shown that routinely violate this principle. Figure 12 shows only a few of the “recommended practice examples” from API-RP-1165. In many of these examples, only subtle color differences, not distinguishable by a substantial fraction of the operator population, are the only means to distinguish a significant status difference.

In one table, API-1165 recommends color coding alarms by type. The well-known best practice is that they are redundantly coded by priority, not type.

Users of API-1165 are therefore advised to pay more attention to the written principles it contains than to the example depictions.

### ISA-101 Human Machine Interfaces for Process Automation Systems

ISA-101 (officially ANSI/ISA-101.01-2015) was begun in October 2008, very close to the time that the first edition of *The High Performance HMI Handbook* was published. PAS is a voting member of the ISA-101 committee. In June 2014, a “final” draft of ISA-101 was sent out to the overall committee for final comment and ballot. The draft was approved by vote but 1,163 comments were returned and had to be resolved. In March 2015, the version reflecting those modifications was sent out for a revote, which passed and the document was released in August 2015. Understand that the ISA document is much more about the “work process” of creating and operating an HMI and not the details of what makes for a good vs. poor HMI. Those that are looking for such detail will be disappointed.

The ISA-101 document is relatively short, containing approximately 44 pages of content and approximately 20 pages of introduction, definitions, and legal notice.

<table>
<thead>
<tr>
<th>State</th>
<th>Background Color</th>
<th>Foreground Color</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Black</td>
<td>Green</td>
<td>1234</td>
</tr>
<tr>
<td>High-High Alarm</td>
<td>Black</td>
<td>Red</td>
<td>1234</td>
</tr>
<tr>
<td>High Alarm</td>
<td>Black</td>
<td>Yellow</td>
<td>1234</td>
</tr>
<tr>
<td>Low Alarm</td>
<td>Black</td>
<td>Yellow</td>
<td>1234</td>
</tr>
<tr>
<td>Low-Low Alarm</td>
<td>Black</td>
<td>Red</td>
<td>1234</td>
</tr>
<tr>
<td>Unknown Error</td>
<td>Black</td>
<td>Blue</td>
<td>1234</td>
</tr>
</tbody>
</table>
ISA-101 contains consistent definitions of various aspects of an HMI. It has the typical text principles of good graphics design, but these are constrained by what is allowable in a standard. Standards are to provide the minimum acceptable, not the optimum. For example, ISA-101 can make a statement like “Color should be used to direct attention and add meaning to the display.” But ISA-101 does not contain anything like the example color palette of Figure 10 in this paper (Part 1), nor should it. Such detail is not within the purview of a standard.

ISA-101 follows the usual Life Cycle approach of other ISA Standards. Life Cycle is a document structure, not a project plan. An example of a Life Cycle for HMI development and operation is supplied. It is mandatory to use some sort of life cycle process to administer an HMI. But the life cycle shown in the document is labeled as an example and is not mandatory.

ISA-101 also makes it mandatory to place changes in the HMI under Management of Change (MOC) procedures, similar to those that govern other changes in the plant and the control system. The details of the MOC procedures are left to the user.

A reader with only brief and rudimentary knowledge of control systems and process control HMI will find nothing new or unusual in ISA-101.

ISA-101 makes it mandatory to create “System Standards.” These are documents that govern the design and creation of the HMI. These are the familiar HMI Philosophy, Style Guide, and Toolkit (Object Library). It is mandatory to apply MOC to the Toolkit. ISA-101 has discussion of ways to create these documents, but there are no examples. Brief descriptions of the contents of such documents are provided (See the end of this white paper for a detailed Table of Contents listing of a comprehensive HMI Philosophy and Style Guide). It is noted that the primary user of the HMI is the operator and design should keep that in mind. There is a small bit of guidance about the use of scripting logic and color.
There is a brief section on the determination of the tasks that a user will accomplish when using the HMI and how those feed the HMI design process.

The activities listed in the ISA-101 life cycle are generally discussed in bullet list and table form. It contains basic (and well known) recommendations such as these:

- The HMI should be consistent and intuitive.
- The information shown should be relevant to the operator.
- Color should not be the only indicator of an important condition.
- Colors chosen should be distinguishable by the operators.
- Auditory warnings should be clear and unambiguous.

There are no examples of proper and improper human factors design and no details such as appropriate color palettes or elements. The only HMI examples in ISA-101 are in a survey-type section providing a list of different types of display styles. Each style is accompanied by a small, intentionally non-detailed example, typically of about one square inch in size. Figure 14 shows a few of those examples in their actual sizes.

ISA-101 mentions the concept of display hierarchy with discussion of Level 1, 2, 3, and 4 displays. Each has an example, and those have been made intentionally undetailed and simplified. The descriptions of the different levels contain no unusual items. Here, for example, are the ISA-101 Level 1, 2, and 3 display examples.

The reader is invited to compare these to Figures 33, 34, and 35 in Part 1 of this white paper.
ISA-101 finishes by providing brief descriptions of the following methods for interacting with an HMI.

- Data entry in fields.
- Entering and showing numbers.
- Entering and showing text.
- Entering commands.
- Designing buttons.
- Using faceplates.
- Navigation – various common methods for navigating from one graphic to another are discussed, such as hierarchical menus and navigation buttons.
- User access and security are briefly mentioned.

In ISA-101, user training in use of the HMI is mandatory. There is brief discussion of a list of things that the training should cover, such as interpreting screen symbols, manipulating the controls, and navigating from screen to screen. If non-operators are also expected to use the HMI, they are expected to be trained as well.
In summary, the publication of ISA-101 is an important step in the field of HMI. ISA-101 is a short document containing some generally well-known and basic principles of HMI design. Its only mandatory requirements are to have an HMI Philosophy, Style Guide, and Object Library, to apply MOC to the HMI, and to provide for user training. ISA-101 contains no detailed examples and does not provide detailed design guidance. For those, the reader will need to seek other sources of expertise. ISA plans to create additional “Technical Reports” on ISA-101, but these typically take from two to six years to publish.

The PAS Seven Step HPHMI Work Process

There is a seven step methodology for the development of an HPHMI with more detail in The High Performance HMI Handbook.

**Step 1:** Adopt a High Performance HMI philosophy, Style Guide, and Object Library. You must have a written set of principles detailing the proper way to construct and implement a High Performance HMI.

**Step 2:** Assess and benchmark existing graphics against the HPHMI philosophy. It is necessary to know your starting point and have a gap analysis.

**Step 3:** Determine specific performance and goal objectives for the control of the operation and for all modes of operation. These are such factors as:

- Safety parameters/limits.
- Production rate.
- Run length.

![Figure 17: ISA-101 Example Level 3 Graphic](image-url)
● Efficiency.
● Equipment health.
● Environmental (i.e., emission control).
● Production cost.
● Quality.
● Reliability.

It is important to document these along with their goals and targets. This is rarely done and is one reason for the current poor state of most HMIs.

**Step 4:** Perform task analysis to determine the control monitoring and manipulations needed to achieve the performance and goal objectives. This is a simple step involving the determination of which specific controls and measurements are used to accomplish the operation’s goal objectives. The answer determines the content of each Level 2, 3, and 4 graphic.

**Step 5:** Design High Performance graphics using the design principles in the HMI philosophy and elements from the style guide and object library to address the identified tasks.

**Step 6:** Install, commission, and provide training on the new HMI.

**Step 7:** Control, maintain, and periodically reassess the HMI performance.

**HPHMI Implementation on a Budget**

While desirable, it is not necessary to replace all (or any) of your existing graphics to obtain much of the benefit of HPHMI. A partial implementation can provide most of the benefits with minimum disruption. A partial implementation involves:

- **ALL EXISTING GRAPHICS ARE KEPT ON THE SYSTEM.** This eliminates almost all objections to HMI improvement.
- Design and deploy new Level 1, Level 2, and Abnormal Situation Management graphics designed with HPHMI principles. This is generally around 20 or so graphics.
- Existing graphics can be designated as Level 3 (which is generally what they actually are) and navigation paths to them altered.
- Improvements to those existing Level 3s (correcting color choices, adding status indications, adding embedded trends, and providing proper context) can be made over time as desired. Yes, there will be inconsistency between the HPHMI graphics and the existing ones. But in examining hundreds of existing HMIs, we have yet to find one that did not already have significant inconsistencies within itself. Operators can handle this with no problem.
Experience has shown that the operators will begin to use the High Performance Level 2 graphics preferentially for normal operation and abnormal situation detection. Why? Because they are BETTER for the purpose. They will use the existing Level 3 graphics for the detailed troubleshooting purposes that they are most suited to support.

Any facility can afford about twenty new graphics! A High Performance HMI is affordable.

**Conclusion**

The most important job of an operator is to detect and successfully respond to an abnormal situation. The HMI is the means by which the operator accomplishes this task. Existing HMIs are woefully inadequate for this purpose. They were generally designed in an era when proper practices were unknown, and the resistance to change has kept those graphics in commission for two or more decades.

The principles of High Performance HMI are specifically developed to deal with the needs of today’s operators and the complex systems they manage. A High Performance HMI is designed to be the best tool for operator interaction with the process control system. It is designed with these important capabilities in mind:

- Provision of an easily monitored overview of the equipment under the operator’s control.
- Ease in maintaining full situation awareness of the span of a large process.
- Early detection and clear depiction of abnormal conditions.
- Effective resolution methods for abnormal situations.
- Embedding easily accessible and relevant knowledge into the control system.

The benefits of such an HMI are more than just reducing human error and avoiding abnormal and unsafe operations. The HMI becomes an effective operational tool for maximizing production, reliability, efficiency, quality, and profitability.

Industry is now recognizing the need and benefits of improved HMIs. Dozens of major companies are in the process of HMI modernization and see it as not only a safety initiative, but a cost-saving and productivity-enhancing one as well.

The functionality and effectiveness of our process automation systems can be greatly enhanced if redesigned in accordance with proper HMI principles. A High Performance HMI is both practical and achievable.
Typical Table of Contents of an HPHMI Philosophy and Style Guide

High Performance HMI Philosophy Example Table of Contents
Note: All sub-sections are not shown.

1.0 Introduction
   1.1 Purpose and Use of a High Performance HMI Philosophy
   1.2 Purpose and Function of the Operator HMI
   1.3 Common but Improper HMI Practices
   1.4 Functional Description of HMI Elements
   1.5 Level 1 Process Area Overview Display
   1.6 Level 2 Process Unit Control Display
   1.7 Level 3 Process Unit Detail Display
   1.8 Level 4 Process Unit Support Display
   1.9 Special Purpose Graphics for Specific Abnormal Situations
   1.10 Display Content
   1.11 Display Layout
   1.12 Display Navigation
   1.13 Alarm Management Features

2.0 HMI Design Process
   2.1 Step 1 - Adopt a High Performance HMI Philosophy, Style Guide, and Object Library
   2.2 Step 2 - Assess and benchmark existing graphics against the HMI Philosophy
   2.3 Step 3 - Determine specific performance and goal objectives for the control of the process
   2.4 Step 4 - Perform task analysis to determine the control manipulations needed to achieve the Performance and Goal objectives
   2.5 Step 5 - Design and build High Performance Graphics using the design principles in the HMI Philosophy and elements from the Style Guide and Object Library, to address the identified tasks
   2.6 Step 6 - Install, commission, and provide training on the new HMI
   2.7 Step 7 - Control, maintain, and periodically reassess the HMI performance

3.0 Purpose and Use of an HMI Style Guide and Object Library
   3.1 DCS Specificity
   3.2 Object Library Contents and Usage

4.0 HMI Performance Monitoring and Ongoing Assessment

5.0 HMI Management of Change (MOC) and Maintenance

6.0 Control Room Factors
   6.1 Control Room Design Factors
   6.2 Control Room Work Practices
   6.3 Operator Console Design
   6.4 Operator Work Practices

6.0 References
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Purpose and Use of an HMI Style Guide</td>
</tr>
<tr>
<td>2.0</td>
<td>Control System Specificity</td>
</tr>
<tr>
<td>3.0</td>
<td>HMI Development Work Process</td>
</tr>
<tr>
<td>4.0</td>
<td>Object Library – Description and Use</td>
</tr>
<tr>
<td>5.0</td>
<td>Display Concepts, Objectives, and Content</td>
</tr>
<tr>
<td>5.1</td>
<td>Level 1 Display – Process Overview</td>
</tr>
<tr>
<td>5.2</td>
<td>Level 2 Displays – Process Unit Operating Graphics</td>
</tr>
<tr>
<td>5.3</td>
<td>Level 3 Displays – Process Detail Displays</td>
</tr>
<tr>
<td>5.4</td>
<td>Level 4 Displays – Process Support and Diagnostic Displays</td>
</tr>
<tr>
<td>6.0</td>
<td>Global System Display Defaults</td>
</tr>
<tr>
<td>7.0</td>
<td>Operator Interaction Methodologies</td>
</tr>
<tr>
<td>7.1</td>
<td>Standard DCS Functionality Usage</td>
</tr>
<tr>
<td>7.2</td>
<td>Change Zones and Faceplates</td>
</tr>
<tr>
<td>7.3</td>
<td>Standard Display Templates</td>
</tr>
<tr>
<td>7.4</td>
<td>Point Manipulation and Faceplates</td>
</tr>
<tr>
<td>7.5</td>
<td>Window Management and Yoking</td>
</tr>
<tr>
<td>8.0</td>
<td>Display Layout</td>
</tr>
<tr>
<td>9.0</td>
<td>Navigation Methods and Practices</td>
</tr>
<tr>
<td>9.1</td>
<td>Programmable Buttons and Keys</td>
</tr>
<tr>
<td>9.2</td>
<td>Keyboards, Menus, and Tab-based Navigation</td>
</tr>
<tr>
<td>9.3</td>
<td>Target-Based Navigation</td>
</tr>
<tr>
<td>9.4</td>
<td>Pointing and Selection Devices</td>
</tr>
<tr>
<td>10.0</td>
<td>Basic Principles of Process Depiction</td>
</tr>
<tr>
<td>10.1</td>
<td>The Proper Role of the P&amp;ID View Element</td>
</tr>
<tr>
<td>10.2</td>
<td>High Performance Display Elements</td>
</tr>
<tr>
<td>11.0</td>
<td>The Proper Use, Implementation, and Importance of Trends</td>
</tr>
<tr>
<td>12.0</td>
<td>Color Palette and Usage</td>
</tr>
<tr>
<td>12.1</td>
<td>Color Palette Definitions &amp; Settings</td>
</tr>
<tr>
<td>12.2</td>
<td>The Role of Color in Situation Awareness</td>
</tr>
<tr>
<td>12.3</td>
<td>Designing for Color-Deficiencies: Coding Redundancy</td>
</tr>
<tr>
<td>13.0</td>
<td>Detailed Display Element Specification and Functionality</td>
</tr>
<tr>
<td>13.1</td>
<td>Depiction of Lines and Labeling</td>
</tr>
<tr>
<td>13.2</td>
<td>Depiction of Static Text, Lists, Tables, and Similar Structures</td>
</tr>
<tr>
<td>13.3</td>
<td>Vessels and Other Static Equipment</td>
</tr>
<tr>
<td>13.4</td>
<td>Depicting Dynamic Equipment</td>
</tr>
<tr>
<td>13.5</td>
<td>Depicting Analog and Digital Values</td>
</tr>
<tr>
<td>13.6</td>
<td>At a Glance Performance Indicators</td>
</tr>
<tr>
<td>13.7</td>
<td>Depicting Controllers</td>
</tr>
<tr>
<td>13.8</td>
<td>Device Position Feedback</td>
</tr>
<tr>
<td>13.9</td>
<td>Vessel Liquid Levels</td>
</tr>
<tr>
<td>13.10</td>
<td>Depiction of Point Names</td>
</tr>
</tbody>
</table>
13.11 Temperature, Pressure, and Similar Profiles
13.12 Startup and Checklist Elements
13.13 Plan vs. Actual
13.14 Depicting Economic Constraints
13.15 Production Extrapolation
13.16 Dynamic Shapes and Elements Library
13.17 Data Input Mechanisms and Safeguards
13.18 Shutdown Activation Elements
13.19 Depicting Valves and Other Final Control Elements
13.20 Interlock and Logic Elements and Displays

14.0 Display Naming Convention & File Storage Naming/Pathnames

15.0 Alarm Functionality
15.1 Proper Configuration of the Alarm Summary Display
15.2 Proper Depiction of Alarms
15.3 Proper Settings for Audible Alarm Tones
15.4 Abnormal Condition Indications
15.5 Alarm Management Functionality
15.6 Alarm and Graphic Association
15.7 Operator Alarm Response
15.8 Depiction and Alarming of Instrument Malfunction
15.9 Alarm Shelving Depiction and Functionality
15.10 State-Based Alarming
15.11 Alarm Flood Suppression
15.12 Operator Alert System

16.0 Special Purpose Graphics
16.1 Startup and Shutdown Assistance
16.2 Expected Abnormal Situations
16.4 Product Change
16.5 Geographic Screens

17.0 Depiction of Programmatic Functionality

18.0 Display Call-up Speed and Performance Requirements

19.0 Advanced Process Control (APC) Application, Functionality, and Depiction

20.0 Standardized Abbreviations List and Engineering Unit Descriptors

21.0 Standard Tools and Display Creation Methodologies

22.0 System Backup

23.0 Management of Change

24.0 Standardized Abbreviations and Engineering Unit Descriptors
About the Authors

Bill R. Hollifield, PAS Principal Alarm Management and HMI Consultant

Bill is the Principal Consultant responsible for the PAS work processes and intellectual property in the areas of both Alarm Management and High Performance HMI. He is a member of the American Petroleum Institute’s API RP-1167 Alarm Management Recommended Practice committee, the ISA SP-18 Alarm Management committee, the ISA SP101 HMI committee, and the Engineering Equipment and Materials Users Association (EEMUA) Industry Review Group.

Bill has multi-company, international experience in all aspects of Alarm Management and HMI development. He has 28 years of experience in the petrochemical industry in engineering and operations, and an additional 12 years in alarm management and HMI software and services for the petrochemical, power generation, pipeline, pharmaceutical, and mining industries.


Bill has authored several papers on Alarm Management and HMI, and is a regular presenter on such topics in such venues as API, ISA, and Electric Power symposiums. He has a BSME from Louisiana Tech University and an MBA from the University of Houston. In 2014, Bill was made an ISA Fellow.

Hector R. Perez, PAS High Performance HMI Product Manager

Hector oversees the High Performance HMI business line at PAS. He is a chief designer of High Performance graphics intended to facilitate situation awareness in a variety of industries. At PAS, Hector oversees PAS software directions to improve product design and capabilities.

Prior to working with PAS, Hector was a senior engineer at Schlumberger. His strength in design contributed to his success in creating new and improved HMIs for reservoir evaluation services and interfaces for business Key Performance Indicator tracking.

In addition to his expertise in High Performance HMI, Hector has widespread experience in all aspects of Alarm Management. He has facilitated numerous Alarm Management workshops, conducted alarm rationalization projects, and developed Alarm Philosophy documents for a wide range of clients in the petrochemical, power generation, pipeline, and mining industries.

Hector has authored technical articles on High Performance HMI. In 2009, he and Bill collaborated with the Electrical Power Research Institute (EPRI) on a comparative research study evaluating High Performance graphics and operator effectiveness. Hector holds a Bachelor of Science in Chemical Engineering from Rice University.
References


About PAS

PAS Global, LLC is a leading provider of software solutions for process safety, cybersecurity, and asset reliability to the energy, process, and power industries worldwide. PAS solutions include industrial control system cybersecurity, automation asset management, alarm management, high performance HMI, boundary management, and control loop performance optimization. PAS solutions are installed in over 1,000 facilities worldwide with more than 40,000 users.

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